Technical Memorandum No. 3

"IMPACT PRESSURE AND TEMPERATURE PROFILES IN A NON-ISOTHERMAL JET DISCHARGING INTO A DUCT"

by

R. D. Danielson and Arnold Kivnick

Issued in Conjunction with the Final Report on the Program

"Mixing of Fluid Streams"

Contract N6-ori-071(11)
with the
Office of Naval Research

University of Illinois

Urbana, Illinois

September 30, 1953

Distribution List

Copies	Government Agencies	Copy No.
15	ONR, Washington, Attn: Fluid Mech. Br. (Code 426)	1-15
8	Biological Dept., Camp Detrick, Attn: Dr. J. B. Bateman	16-23
1	ONR, Boston 10, Mass.	24
1	ONR, New York	25
2	ONR, Chicago	26-27
1	ONR, San Francisco	28
1	ONR, Pasadena	29
2	ONR, F.P.O. 100, New York	30-31
1	ONR, Washington, Attn: Mechanics Div. (Code 3600)	32
1	BuAer, Washington, Attn; Capt. W.S. Diehl (AER-23)	33
1	BuOrd, Washington, Attn: Code Re9	34
3	Wright Air Dev. Cen., Dayton, Mr. L.S. Wasserman, Flight Res. Lab	35-37
1	Air Res. and Dev. Command, Baltimore, Dr. T. Theodorsen	38
1	BuAer, Washington, Attn: Mr. J.S. Attinello	39
1	Director, David Taylor Mod. Basin, Washington, Attn: Dr. Brode	40
1	Air Materiel Command, Dayton, Air Doc. Div. (MCIDXR)	41
1	Ballistic Res. Lab., Aberdeen, Attn: Mr. R.H. Kent	42
1	Army Chemical Center, Attn: Dr. D. MacRae	43
1	NACA, Washington	44
1	NACA, Langley Aero. Lab., Langley Air Force Base, Va.	45
1	NACA, Ames Aero. Lab., Moffett Air Force Base, Calif.	46
1	NACA, Lewis Flight Propulsion Lab., Cleveland	47
1	Dr. Francis H. Clauser, Johns Hopkins Univ., Baltimore	48
1	Dr. Arnold Kuethe, University of Michigan, Ann Arbor	49
1	Dr. Hans W. Lippmann, GAL. CIT, Pasadena	50
1	Dr. G.B. Schubauer, Nat'l Bur. of Stds., Washington	51
1	Dr. R. J. Seeger, NOL, Silver Spring, Md.	52

Copies	Universities and Research Organizations	Copy No.
1	Atlantic Res. Corp., Alexandria, Attn: Dr. A.C. Scurlock	53
1	Polytech. Inst. of Brooklyn, Prof. R.P. Harrington	54
1	GAL, CIT, Pasadena, Attn: Dr. C. B. Millikin	55
1	Jet Prop. Lab., Cal. Tech., Pasadena, Attn: Librarian	56
1	Univ. of Calif., Berkeley, Attn: Dr. R. G. Folsom	57
1	Cornell Aero. Lab., Buffalo, Attn: Dr. J. V. Foa	58
1	Cornell Univ., School of Aero. Eng., Ithaca, Dr. W.R. Sears	59
1	Cornell Univ., School of Aero. Eng., Dr. A. Kantrowitz	60
1	Univ. of Del., Chem. Eng. Dept., Newark, Attn: Dr. K. Wohl	61
1	Harvard Univ., Dept. App. Phys. Engr. Sci., Attn: Prof. H. W. Emmons	62
1	Univ. of Illinois, Attn: Dr. H. F. Johnstone	63
1	Univ. of Illinois, Library	64
1	Univ. of Illinois, Eng. Library	65
1	Univ. of Iowa, Inst. Hydraulic Res., Attn: Dr. H. Rouse	66
1	Johns Hopkins Univ., Dept. Aero. Eng., Prof. S. Corrsin	67

Distribution List (Cont'd)

Copies	Universities and Research Organizations	Copy No.
1	Applied Phys. Lab., Silver Apring, Attn:Supervisor,Tech.Repts.	68
1	Arthur D. Little Co., Attn: Dr. R. V. Kleinschmidt	69
1	MIT, Gas Turbine Lab., Attn: Prof. A. H. Shapiro	70
1	MIT, Guided Missiles Comm., Attn: Supervisor, Tech. Repts.	71
1	MIT, Aero. Eng. Dept., Attn: Dr. J. C. Hunsaker	72
1	MIT, Chem. Eng. Dept., Attn: Prof. G. C. Williams	73
1	MIT, Math. Dept., Attn: Dr. C. C. Lin	74
1	MIT, Mech. Eng. Dept., Attn: Prof. J. H. Keenan	75
1	Univ. of Mich., Dept. Aero. Eng., Attn: Prof. E.W. Conlon	76
1	Princeton Univ., Aero. Eng. Dept., Attn: Prof. L. Lees	77
1	Princeton Univ., Gugg. Jet Prop. Lab., Attn: Prof. J.V. Charyk	78
1	Purdue Univ., Attn: Prof. M. J. Zucrow	79
1	Stanford Univ., Attn: Prof. P. A. Leighton	80
1	Univ. of Texas, Attn: Dr. M. J. Thompson	81
1	Univ. of Wichita, Aero. Eng. Dept., Attn: Mr. K. Razak	82
1	Appd. Phys. Lab., Silver Spring, Attn: Dr. F.N. Frenkiel	83
1	Purdue Univ., Dept. Chem., Met. Eng., Attn: Dr. E.W. Comings	84
1	Dr. T. Baron, Shell Devel. Co., Emeryville	85
1	Dr. A.E. Weller, Battelle Inst., Columbus	86
1	Dr. E. C. Hsu, Iowa Inst. of Hydraulic Res., Iowa City	87
1	Dr. S. I. Pai, Univ. of Maryland, College Pk.	88
1	Dr. Irvin Glassman, Guggenheim Lab., Princeton Univ.	89
1	Mr. Frank Kreith, Dept. Mech. Eng., Univ. of Cal., Berkeley	90
1	Nat. Res. Corp., Cambridge, Attn: Librarian	91
1	Mr. G. J. Maslach, Dept. Mech. Eng., Univ. Cal., Berkeley	92
1	Prof. R. W. McCloy, Univ. of Ill., Dept. Aero. Eng.	93
1	Prof. Paul Torda, Univ. of Ill., Dept. Aero. Eng.	94
1	Prof. Stillwell, Univ. of Ill., Dept. Aero. Eng.	95
1	Prof. H. H. Korst, Univ. of Ill., Dept. Mech. Eng.	96
1	Mr. S. F. Gilman, Univ. of Ill., Dept. Mech. Eng.	97
1	James Forrestal Res. Center, Princeton Univ., Attn: Librarian	98
1	Dr. Arnold Kivnick, Penn. Salt Mfg. Co., Philadelphia	99
1	Dr. L. G. Alexander, Oak Ridge, Tennessee	100

IMPACT PRESSURE AND TEMPERATURE PROFILES IN A NON-ISOTHERMAL JET DISCHARGING INTO A DUCT

R. D. Danielson and A. Kivnick

Earlier work with air jets discharging into ducts showed the existence of velocity profiles, near the duct walls, which seemed abnormal. The observed velocity gradients could not be explained by the usual descriptions of normal boundary layer build-up. The abnormality occurred for isothermal systems (4) as well as for hot-air jets discharging into cold air (3). Alexander and co-workers (1) suggest that the explanation might be that of "choking," that is, some of the air downstream from the jet was reversing its direction of flow, returning along the duct walls to the jet and becoming entrained again. This would mean that the amount of secondary air being sucked from the room into the open inlet end of the duct was less than the entrainment "requirements." Although no actual backflow was observed, the forward flow was much slower near the wall than was expected, so the observed results were described as being caused by incipient choking.

The ducts used for the prior work had sudden entrances for the secondary air. It was felt that perhaps choking could be reduced by using a tapered entrance section. The purpose of the new study was to determine the effect of such an improved entrance section on the velocity profiles in the duct.

The new work is described in detail in a Master's thesis by Danielson (2). Hot air at about 200°F. discharged at approximately 600 ft./sec. through an A.S.M.E. long-radius nozzle (both 0.750 and

0.898 inch diameters were used) into a 3.8 inch I.D. duct. The duct was 10 ft. long and was open at both ends to room air at about 80°F. The suction end of the duct was fitted to an A.S.M.E. elliptical section flow nozzle with a maximum I.D. of about 12 inches. Temperature and pressure surveys were made at numerous locations in the duct. Except for the change in duct entry, the equipment and procedure were the same as those used for the earlier work of White and of Henze.

The new results showed that the abnormal velocity profiles were no longer present. Apparently choking in a duct can be eliminated by the use of a smooth transition entry section on the duct. Rigorously speaking, this does not necessarily mean that the prior explanation of choking has been proved.

The temperature profiles obtained during the earlier studies (with the sudden entry section) did not give much support to the choking (or reversed flow) hypothesis. Near the jet, the temperature change along a radius fell rapidly and smoothly from the temperature of the jet to that of the ambient air which was being entrained. There was nothing about the temperature distribution to suggest that any air from downstream was returning to the nozzle or that it was even on the verge of returning. The new temperature profiles obtained by Danielson agree closely with the earlier measurements.

In conclusion, if a sudden entrance section is used for the secondary air, the air flow near the duct wall at locations close to the nozzle will be much slower than expected from simple flow theories. If a convergent entry is used, the air flow pattern appears normal. For some unknown reason the temperature profile is not affected by the entry shape.

Bibliography

1. Alexander, L. G., Comings, E. W., Grimmett, H. L., and White, E. A., Technical Report No. 11, Contract N6-ori-071(11), Engineering Experiment Station, University of Illinois (May 1, 1952).

2. Danielson, R. D., M.S. Thesis in Chemical Engineering, University of Illinois, 1953.

3. Henze, E. D., M.S. Thesis in Chemical Engineering, University of Illinois, 1951.

4. White, E. A. Unpublished data, Chemical Engineering Division, Engineering Experiment Station, University of Illinois.